# ENHANCING ENERGY EFFICIENCY

TIM NEUHAUS, PENG BAI, THEO SCHROOTEN, GUNNAR-MARCEL KLEIN AND ASTRID KÖGEL, INTENSIV-FILTER GMBH & CO. KG, GERMANY, DISCUSS INCREASING ENERGY EFFICIENCY IN INDUSTRIAL GAS CLEANING.

**Abstract**

Pressure losses in industrial bag filters and hence operating costs for industrial gas cleaning are primarily caused by the filter cake that is built up on the filter medium during surface filtration. Comparative tests as in VDI 3926 show that, with Intensiv-Filter ProTex filter media, the gradient for the rise in differential pressure following regular cleaning and hence the average pressure loss for a bag filter can be reduced. ProTex filter media are presented in this article both for the low temperature and high temperature ranges. A further increase in energy efficiency is attained by shortening cleaning cycles. This is presented within this article as Three E Technology – Enhanced Energy Efficiency. This technology (Three E with ProTex filter media), can lower operating costs by up to 40% compared to conventional bag filters.

Figure 1. REM images of filter media surfaces: ProTex PES x200 (l.); ProTex PMIA x200 (m.); ePTFE/membrane x1000 (r).

## Introduction

Due to tight requirements for resources, increasing energy efficiency in industrial processes has come into focus with the development of new techniques and processes and optimisation of existing ones – not just in Europe but throughout the world. Energy consumption (and specific energy costs) is increasingly a decisive factor when choosing a process. The reduction of $CO_2$ emissions as an environmental policy goal has increased this trend even further.

Fan power accounts for more than 80% of energy consumption in the gas cleaning process. The product of volume flow and pressure loss in the filter plant constitutes the power required. Volume flow is fixed depending on the process, so pressure loss alone carries potential for optimisation.

The greatest share of pressure loss in a bag filter is caused by the filter cake and irreversible deposition of particles in the filter medium.[1, 2] These conditions are dependent on the composition of the cake (thickness, compression, porosity), dust and gas properties (dust and gas density, particle shape, agglomeration characteristics, moisture, etc.) and the properties of the filter medium (surface composition, fibre titre, homogeneity, pore size and distribution, etc.)

Conventional needlefelts, as have been used in bag filters for many years now, deposit high dust quantities deep in the medium during the initial filtration phase and only perform filtration itself once the filter cake has been built up. This leads to the initial, very low residual pressure loss rising severely as the length of operation increases.[3]

Although alternative filter media with an ePTFE membrane, which have been in use for several years now, demonstrate a low pressure gradient in the pressure loss curve, they start with a very high residual pressure loss, which is attributable to the very low pore width of the membrane and irreversible dust deposits in the membrane.

Use of microfibres in needlefelts originally had the goal of increasing the separation efficiency of conventional filter media. Due to the arrangement, particularly on the upstream side, depositing of particles deep in the medium can be avoided, however, and a disproportionately high increase of the pressure gradient in the pressure loss curve can be prevented. ProTex filter media, which have been developed within the framework of a sampling series of microfibre media of various mixtures and fibre structures, combine these properties, hence providing optimised surface filtration.

**Table 1. Results of the testing of different filter media for low temperature applications in accordance with VDI 3926. Test dust: Pural Sb**

| | | ePTFE (PES scrim) serial type 1 | ePTFE (PES scrim) serial type 2 | PES microfibre needle felt, serial type | ProTex PES |
|---|---|---|---|---|---|
| **New condition** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 49 | 55 | 117 | 112 |
| Residual pressure loss | [Pa] | 120 | 92 | 65 | 63 |
| **After ageing and stabilisation cycles** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 13 | 18 | 35 | 36 |
| Residual pressure loss | [Pa] | 533 | 350 | 155 | 155 |
| Cycle time | [s] | 603 | 1164 | 1114 | 1505 |
| **After operating with filter, in aged condition** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 13 | 18 | 39 | 40 |
| Residual pressure loss | [Pa] | 530 | 318 | 155 | 158 |
| Clean gas concentration | [mg/m³] | <0.1 | <0.1 | <0.1 | <0.1 |

The combination of the ProTex filter media with an operating mode using short cycle times (≤ 150 s) allows further potential for the reduction of energy consumption by the fan. The new Three E process has no negative effects on clean gas concentration due to the higher separation efficiency of the ProTex filter medium. The increased compressed air consumption for cleaning is more than compensated by the benefits described above.

In the following, ProTex test results for use in the low temperature range (<140 °C) and the high temperature range (140 - 240 °C) are presented.

## Comparative tests according to VDI 3926

### Test set-up and test conditions

The VDI* guideline 3926 is a tried and tested assessment for comparative testing of filter media, which to a great extent has been adopted in the draft for the ISO standard.[5,6] In accordance with this, filter media tests were carried out at Intensiv-Filter on a type 1 test rig. Contrary to the guideline, the first 30 cycles of the test, which are designed solely for characterisation of the medium, have been omitted. Furthermore, a higher raw gas dust concentration of 10 g/m³ was selected. The following 10 pressure-differential-controlled cycles for stabilisation of the filtration process were retained. The last of these cycles was used for characterisation of the filter medium and for comparison of the filter media in respect of cycle time. To improve comparability of the results, the last 30 cycles were not pressure-differential-controlled but rather cleaned at a constant cycle time of 600 s.

The tests were conducted with different test dusts. Instead of Pural Nf, the test dust prescribed in the standard, Pural Sb ($Al_2O_3$) was used, which features a very low agglomeration tendency and high flowability. Experience has shown that the Pural Sb test dust is better suited to reproducing real conditions than Pural Nf.[7] As additional test dusts, a finely-dispersed Portland cement dust was used for ProTex low temperature application (CEM III/A 52.5 N-HS/NA, Blaine 5900, d50= 8 µm) and a dust obtained from a cement raw mill used for high temperature application known as raw material (approximately 90% $CaCO_3$ or limestone). Both cement dust and limestone demonstrate strong agglomeration characteristics.

**Table 2. Results of the testing of different filter media for low temperature applications in accordance with VDI 3926. Test dust: cement**

| | | ePTFE (PES scrim) serial type 1 | PES microfibre needle felt, serial type | ProTex PES |
|---|---|---|---|---|
| **New condition** | | | | |
| Air permeability | [l/dm²/min@200Pa] | 49 | 117 | 112 |
| Residual pressure loss | [Pa] | 120 | 65 | 63 |
| **After ageing and stabilisation cycles** | | | | |
| Air permeability | [l/dm²/min@200Pa] | 13 | 24 | 29 |
| Residual pressure loss | [Pa] | 458 | 247 | 227 |
| Cycle time | [s] | 1147 | 1451 | 1556 |
| **After operating with filter in aged condition** | | | | |
| Air permeability | [l/dm²/min@200Pa] | 14 | 29 | 32 |
| Residual pressure loss | [Pa] | 359 | 213 | 177 |
| Clean gas concentration | [mg/m³] | <0.1 | <0.1 | <0.1 |

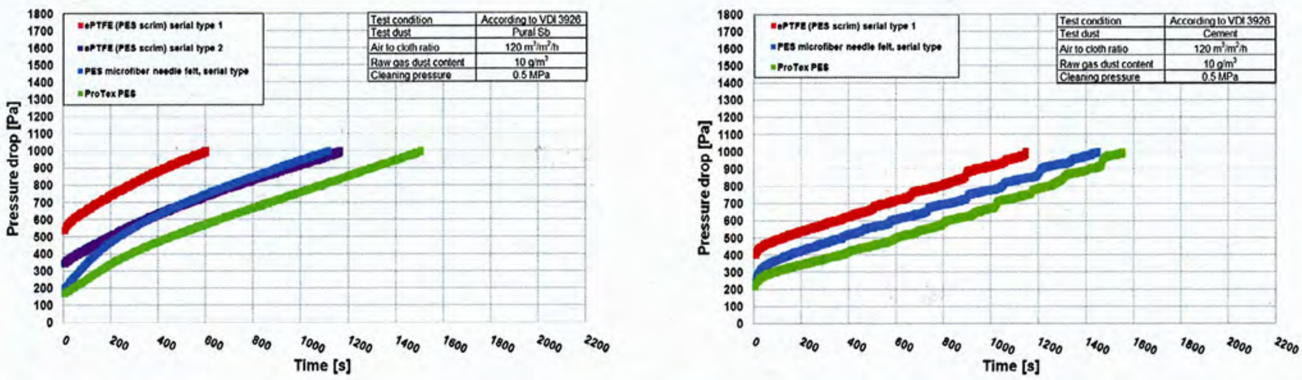



Figure 2. Testing of different filter media for low temperature applications in accordance with VDI 3926; differential pressure curves of the tenth pressure-differential-controlled cycle of the stabilisation phase after ageing.

*With almost 140 000 individual members the Association of German Engineers (VDI) is one of the largest technical-scientific associations in Europe. The VDI covers a wide range of technical topics and communicates this knowledge through studies, technical discussions and congresses or the VDI guidelines that create generally accepted technical rules.

## Selection of the filter media analysed

Test rig studies for the low temperature range were carried out with a polyester microfibre needlefelt, a filter medium with an ePTFE membrane and the ProTex filter medium (PES). For the high temperature range, a series of different polymer-basis filter media were available due to the eclectic and varying requirements in practice. Typical materials are PMIA (m-aramide, Nomex®), polyimide, PPS, PTFE and hybrid needlefelts. The corresponding medium for the relevant application was selected depending on the operating temperature, the chemical composition and humidity of the exhaust gas. Optimisation potential of ProTex filter media was therefore examined for all typical polymers in order to be able to provide an optimal energy-saving medium for each application. ProTex filter media presented here and conventional filter media are based on m-aramide and polyimide and comprise microfibres of various mixtures and fibre structures. An ePTFE membrane on fibreglass was used as an additional filter medium, now widely used in the high-temperature range. Figure 1 shows examples of REM images of the filter media examined.

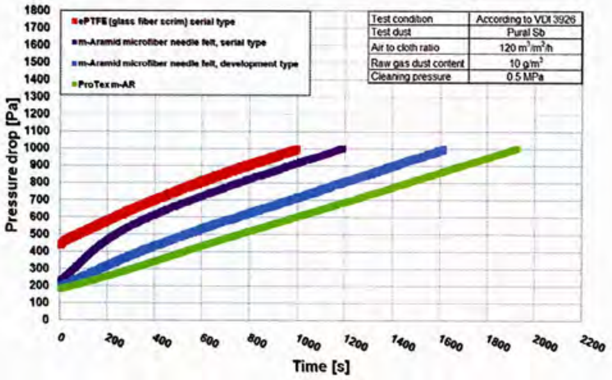
## Test results

The criterion for optimisation potential was minimisation of the pressure loss curve gradient in the first filtration phase after jet-pulse cleaning. The final cycles of the test procedure test were compared. Test results for the low temperature range are summarised in Figure 2 and in Tables 1 and 2. The differential pressure curves shown for the ePTFE membrane demonstrate a minimal pressure gradient directly after cleaning, but a very high residual pressure loss, attributable to the irreversible deposition of dust in the membrane. The conventional microfibre medium exhibited a relatively low residual pressure loss but a high rise in the pressure loss curve directly

**Table 3. Results of the testing of different filter media for high temperature applications in accordance with VDI 3926. Test dust: Pural Sb**

| | | ePTFE (glass fibre scrim) serial type | m-Aramid microfibre needle felt, serial type | m-Aramid microfibre needle felt, development type | ProTex m-AR |
|---|---|---|---|---|---|
| **New condition** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 31 | 100 | 92 | 140 |
| Residual pressure loss | [Pa] | 175 | 72 | 63 | 73 |
| **After operating with filter in aged condition** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 12 | 29 | 31 | 33 |
| Residual pressure loss | [Pa] | 436 | 204 | 185 | 180 |
| Clean gas concentration | [mg/m³] | <0.1 | <0.1 | <0.1 | <0.1 |

| | | PI needle felt, serial type | PI needle felt, development type | ProTex PI |
|---|---|---|---|---|
| **New condition** | | | | |
| Air permeability | [l/dm²/min@200Pa] | 61 | 121 | 159 |
| Residual pressure loss | [Pa] | 103 | 65 | 57 |
| **After operating with filter in aged condition** | | | | |
| Air permeability | [l/dm²/min@200Pa] | 22 | 42 | 51 |
| Residual pressure loss | [Pa] | 278 | 173 | 148 |
| Clean gas concentration | [mg/m³] | <0.1 | <0.1 | <0.1 |



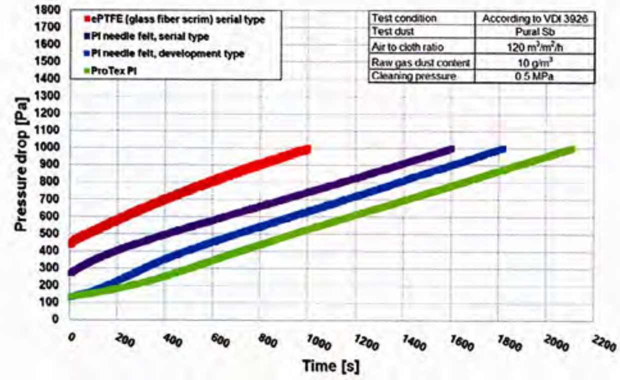




Figure 3. Testing of various filter media for high-temperature applications using an ePTFE membrane, PMIA (m-aramide, Nomex®) and PI (polyimide), differential pressure curves for the final, differential pressure-controlled cycle of the test according to VDI 3926. Test dust: Pural Sb.

after cleaning, so that the pressure loss level reached at the end of the cycle was approximately the same as that for the ePTFE membrane. The ProTex filter medium demonstrated both a small gradient on the pressure loss curve and a low residual pressure loss for both test dusts. Irregularities in the linear progression of the curve during tests with cement dust, which increase as the dust cake becomes thicker, can be attributed to compression processes in the dust cake.

Differential pressure curves of the test rig are compared in Figures 3 and 4 and in Tables 3 and 4 for the high-temperature range. Here, too, the ePTFE membrane demonstrates a smaller pressure gradient but high residual pressure losses. This is caused by irreversible blockage of the membrane. Figure 5 shows examples of the surfaces of media tested according to the VDI test. The conventional microfibre filter media show a significantly lower residual pressure loss but also to some extent a severe pressure increase directly after cleaning. Both ProTex PMIA and ProTex PI, on the other hand, demonstrate a virtually linear pressure increase with the lowest residual pressure loss after cleaning. The same trend can also be observed during tests with limestone.

By using the Three E process and the associated reduction of cycle time, a further reduction of pressure loss can be attained. When cycle time is reduced from 300 to 100 s, ProTex shows a reduction of 55% for the low temperature range, rising to more than 60% for the high-pressure range compared to conventional microfibre media. For the better agglomerating dusts - cement and limestone - there is still a reduction of between 35% and 55%.

## Practice-oriented tests on the pilot plant

### Test conditions

The pilot plant comprises a bag filter with 10 filter bags (d = 160 mm, L = 4 m). Two bags at a time are regenerated separately in online mode via a pressure vessel equipped with a membrane valve together with a JetBus cleaning system. The cleaning pressure can be adjusted steplessly between 0.1 and 0.6 MPa by means of a maintenance unit with a pressure reducing valve upstream from the pressure vessel. The volume flow is channelled into the circuit, with the test dust being dispersed continuously into the test air via an infeed area from a buffer reservoir with a metering screw. The dust precipitated onto the filter bags is conveyed via a rotary valve back into the buffer reservoir. A detailed description of the pilot plant can be found in *F&S Filtrieren und Separieren*[4].

The filter bags for the test series in the pilot plant were made from the microfibre medium and the ProTex filter medium described earlier. A conventional PES needlefelt, still used today in many applications, was also included in the test series as a benchmark. The bags were aged by 36 000 cleanings with a cycle time of 25 s, a cleaning pressure of 0.5 MPa, an air-to-cloth ratio of 120 $m^3/m^2/h$ and a dust concentration of 10 $g/m^3$ (Pural Sb test dust). With these parameters, the ageing procedure far exceeded the conditions of the ISO draft standard (2500 with a cycle time of 20 s). The tests were carried out under identical conditions with time-controlled cleaning at cycle times of 300 s, 200 s and 100 s.

### Test results

The upper series of charts in Figure 6 shows the changes in differential pressure over the measuring time with the use of the three filter media described and 300 s cycle time. The value measured for air-to-cloth ratio is shown in parallel on the charts (set to constant 120 $m^3/m^2/h$ with all tests). Again, in the pilot plant too, the average differential pressure (from measurement points on raw gas side and clean gas side) when the ProTex filter medium was

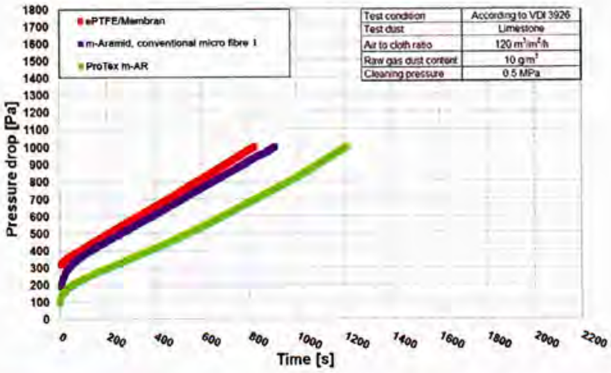



Figure 4. Testing of various filter media for high-temperature applications using an ePTFE/membrane, PMIA (m-aramide, Nomex®) differential pressure curves for the final, differential pressure-controlled cycle of the test according to VDI 3926. Test dust: limestone (raw meal).

**Table 4. Results of the testing of different filter media for high temperature applications in accordance with VDI 3926. Test dust: Limestone (raw meal)**

| | | ePTFE (glass fibre scrim) serial type | m-Aramid conv. microfibre, serial type | m-Aramid conv. microfibre, development type | ProTex m-Aramid |
|---|---|---|---|---|---|
| **New condition** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 34 | 95 | 97 | 145 |
| Residual pressure loss | [Pa] | 176 | 82 | 81 | 62 |
| **After operating with filter in aged condition** | | | | | |
| Air permeability | [l/dm²/min@200Pa] | 17 | 25 | 30 | 37 |
| Residual pressure loss | [Pa] | 444 | 243 | 212 | 191 |
| Clean gas concentration | [mg/m³] | <0.1 | <0.1 | <0.1 | <0.1 |

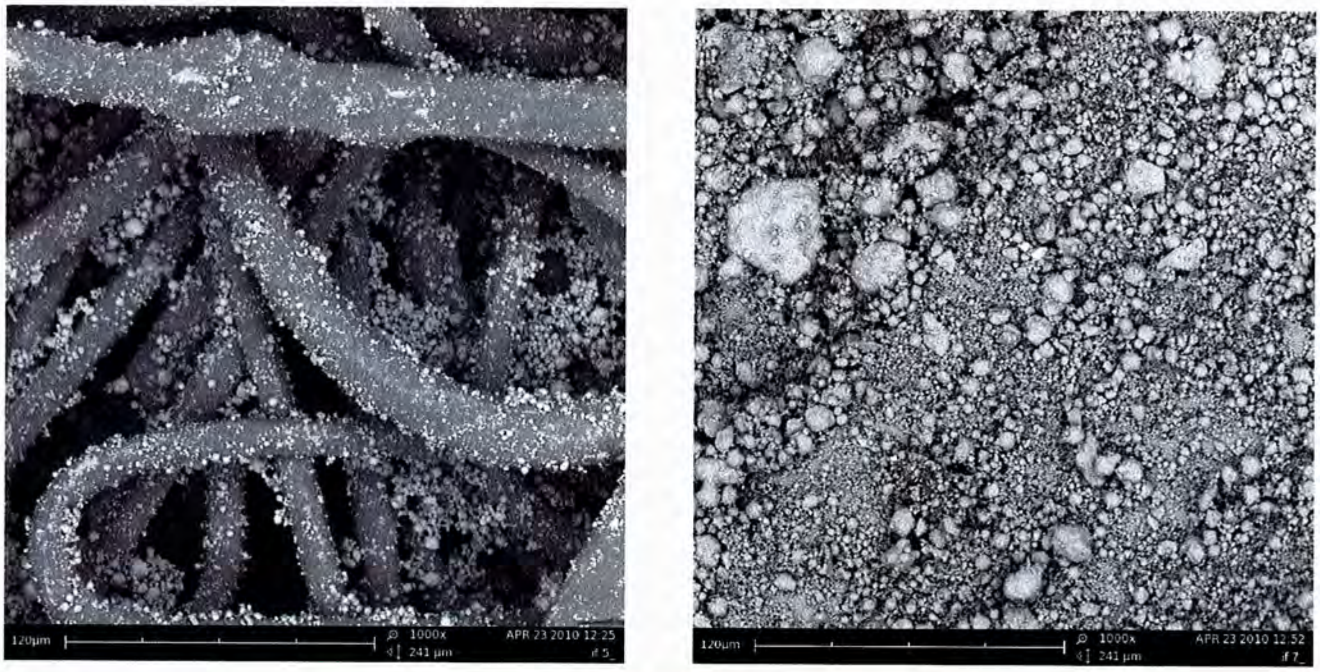



Figure 5. REM images (x1000) of filter media surfaces after testing in accordance with VDI 3926: ProTex PMIA (l.), ePTFE membrane (r).

used was significantly lower than when the conventional microfibre medium was used. The needlefelt (without microfibre) was at a differential pressure level, which was even higher still. It should be noted here that the latter medium exhibited continually increasing residual pressure drops due to its open pore structure, and could not be brought into a quasi-stationary operating state even after the ageing procedure described. Looking at the mean values, the ProTex filter medium shows a pressure loss that is lower by a factor of 1.9 than that of the conventional microfibre medium and lower by a factor of 2.3 than that of the conventional needlefelt.

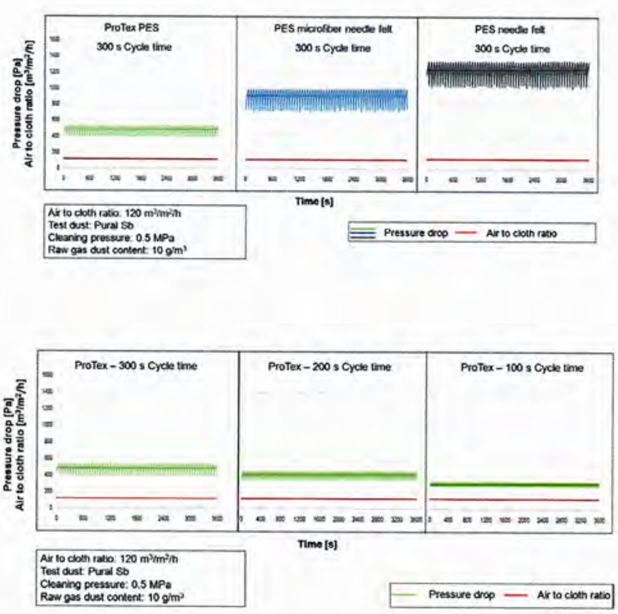



Figure 6. Pressure loss curves for the use of different filter media and variation of cycle time – tests in a 10-bag pilot plant.

The lower series of charts in Figure 6 shows the differential pressure characteristics when using the ProTex filter medium together with reduced cycle times (100 s and 200 s). When the cycle time is reduced to 100 s, the ProTex filter medium attains a mean differential pressure that is less than that of the benchmark by a factor of 4 (needlefelt medium and operation at a cycle time of 300 s).

The conventional needlefelt demonstrated emissions greater than 10 mg/m³, which is a sign of penetration of the particles into the filter medium and an open pore structure. With a cycle time of 200 s the total dust concentration detected in the clean gas was 0.5 mg/m³ for the conventional microfibre medium and 1.7 mg/m³ for the ProTex filter medium. Both filter media are therefore clearly below the limits imposed by TA-Luft (Germany's Technical Instructions on Air Quality Control). When the cycle time was reduced further to 100 s, the concentration for the ProTex filter medium rose slightly to 2.5 mg/m³, still remaining clearly below the values for the needlefelt and below the limits prescribed by law.

## Conclusions and prospects

Optimised surface filtration of ProTex filter media could be demonstrated both for low temperature and high-temperature applications by means of comparative tests. Combined with a reduction of the cycle time and the Three E process used for this, the resulting energy requirements were significantly reduced by the flow resistance of the filter cake and residual pressure loss of the filter medium. Effects on operating costs are shown in Figure 7 based on a conventional jet pulse bag filter and an Intensiv-Filter ProJet mega® bag filter with Three E technology. Owing to the reduction of pressure losses by Three E and ProTex, operating costs can be lowered by up to 40% with Intensiv-Filter installations compared to conventional bag filter systems.

In addition to the option of reducing operating costs, Three E technology naturally also offers the alternative

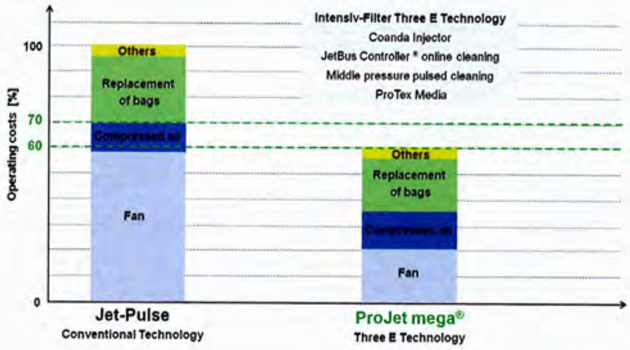



Figure 7. Operating costs of a ProJet mega® filter in online operation with Three E technology and ProTex filter medium in comparison with a jet pulse filter in online operation under standard conditions.

Figure 8. Design features of the new ProJet smart® filter series.

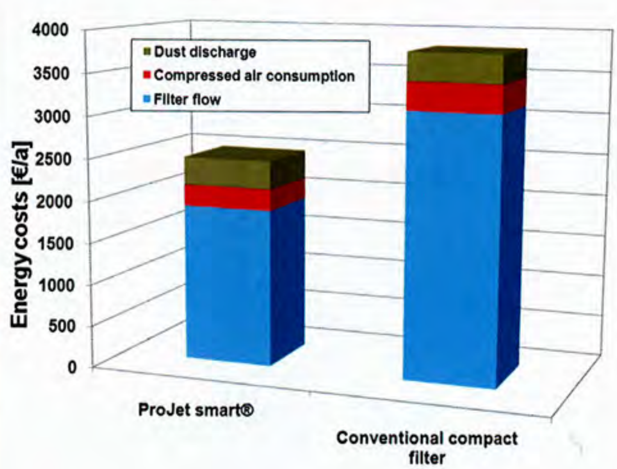



Figure 9. Savings on energy and operating costs for ProJet smart® with ProTex filter media in comparison to a conventionally designed jet pulse filter.

of increasing the air-to-cloth ratio and thereby reducing the size of the dust collector with no change in operating costs when compared with standard conditions. This means Three E is also ideal for expanding the capacity of production plants, where the aim is to increase the volumetric flow of cleaned gas while retaining the existing filter housing.

Further validation testing in the cement industry is currently at the preparation stage. Other high-temperature resistant fibres, such as PPS and PTFE, designed to complete the ProTex filter media portfolio, are currently undergoing testing.

## The new ProJet smart® filters with ProTex PES filter media

Compact filters in the cement and stone/earth industries must provide high-performance suction power at the source of the dust and 100% availability even under changing operating conditions. All filter components must prove their sustained functionality where the operating conditions are extreme and in the event of abrasive dust. The new filter series ProJet smart® (Figure 8) also has inner values, which offer the operator additional benefits. The centrepiece of the filter, i.e. the filter bags and the cleaning system, exhibits a new technology that either enables a higher specific performance of the filter or a considerable reduction in the operating costs and thus the LCC (life cycle costs) for the dedusting plant.

The potential improvement in the air-to-cloth ratio in ProJet smart® is based on the use of the newly developed ProTex filter media generation in combination with the efficient «ideal nozzle» cleaning system. In practice, a reduction of 40% in the average differential pressure can be expected by using the filter, depending on the condition of the dust. Alternatively, the filter can be operated with an increased volume flow if the differential pressure is unchanged. Figure 9 shows the savings on energy and operating costs for ProJet smart® with ProTex filter media in comparison to a conventionally designed jet pulse filter.

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